OPAL-RT TECHNOLOGIES

FROM IMAGINATION TO REAL-TIME

ePowerGrid Real-Time Simulator Family
Designed To Meet Increasing Power System Complexity

From Nanoseconds to Seconds

From Small isolated systems To Micro Grids

To Large Interconnected Grids

Jean Bélanger

Opal-RT Technologies in Brief

COTS-based Real-Time Simulation and HIL Test Systems

- **Established in 1997, Montreal**
  - 20% of annual revenue in R&D
  - 85+ employees

- **Fully Digital Real-Time Simulators**
  - HIL , RCP and PHIL Systems
  - Control and Protection System Tester
- Integrated with MATLAB/SIMULINK and other software
- Multi-core INTEL Computer Cluster
- XILINX FPGA I/O and Processor System

- Subsidiaries in France, USA and India
- Soon in Australia
- Integrator and Distributor Network

Italia, China, Japan, Korea, Taiwan, Singapore

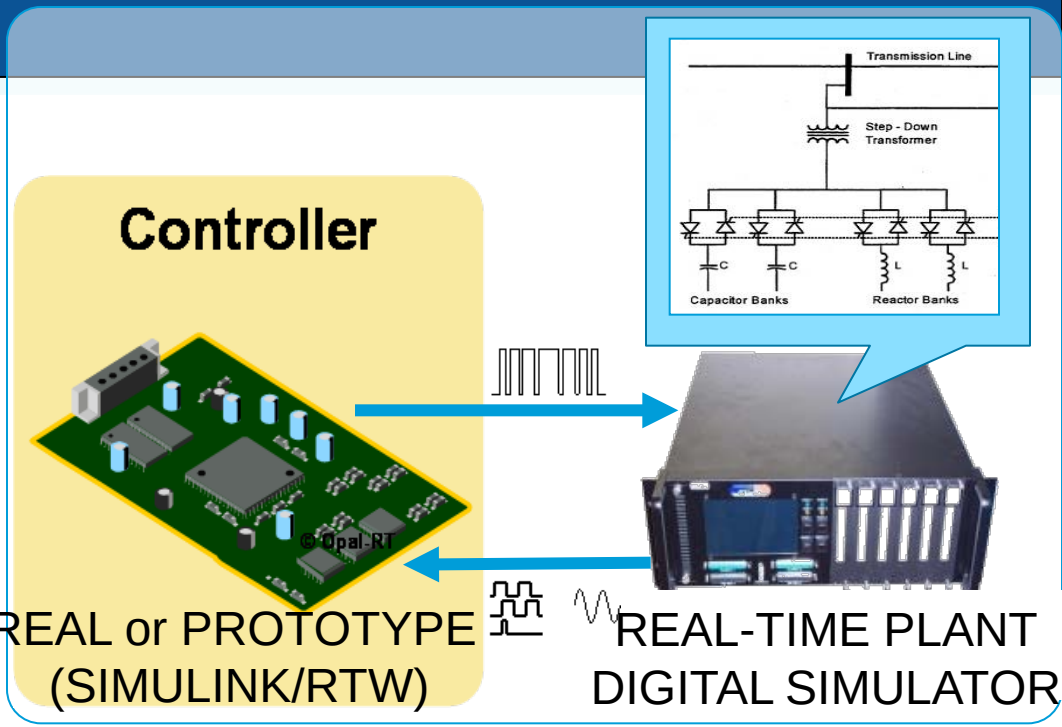
- Aero, Defense, Transportation, Power Electronic, Utilities & Universities
  - Automotive and Off-Highway vehicles OEM and Tier One Suppliers
  - Electric Train and Ship builders and More Electrical Aircrafts R&D Centers
  - Industrial Power Electronic Manufacturers
  - Power grids, micro-grids, distributed generation, PV …

Outline

- What is real-time simulation and HIL
- Evolution of power systems
- Evolution of real-time simulation technologies
- Type of simulation tools vs Application
- Challenges and solutions- Transmision system
- Adddtional challenges for Distribution and micro-grids

What is a Real-Time Simulator?

- Real-Time Computer Integrated with
  - Modeling and Simulation Software (Simulink, SPS , RTW)
  - Input/Output system
  - Real-Time Data Logging
  - CPU Monitoring
  - Host Computer for User Interface and Waveform Display

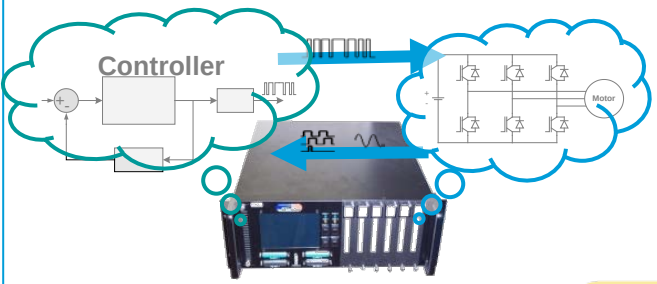


- Designed to Meet Hard Real-Time Constraints for Hardware-in-the Loop
  - All model calculations MUST be completed within the specified time period
  - Must include Real-Time processor monitoring and overrun detection
- Capable of Emulating…
  - Simulated plant;
  - Control systems
  - or both SIMULTANEOUSLY
- … with Good Accuracy
  - Better than 50 us time step
  - Better than 200 nanosecond timing

MODEL BASED DESIGN

Fast Fully Digital Simulation, Software-in-the-loop (SIL)

2



Simulink, SimPowerSystems
variable or fixed-step
Single- or multi-core Windows P

1

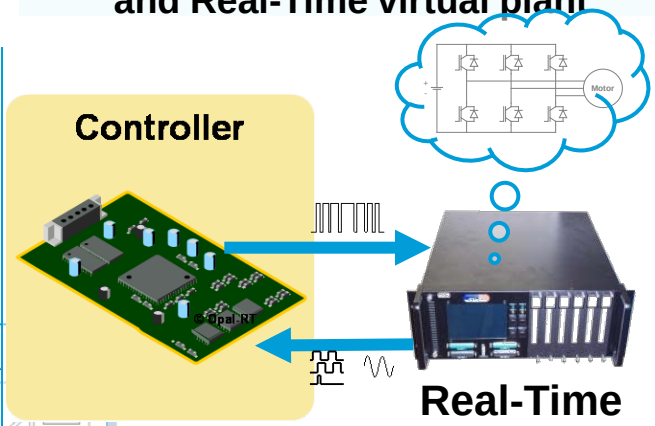
SPECIFICATION

6

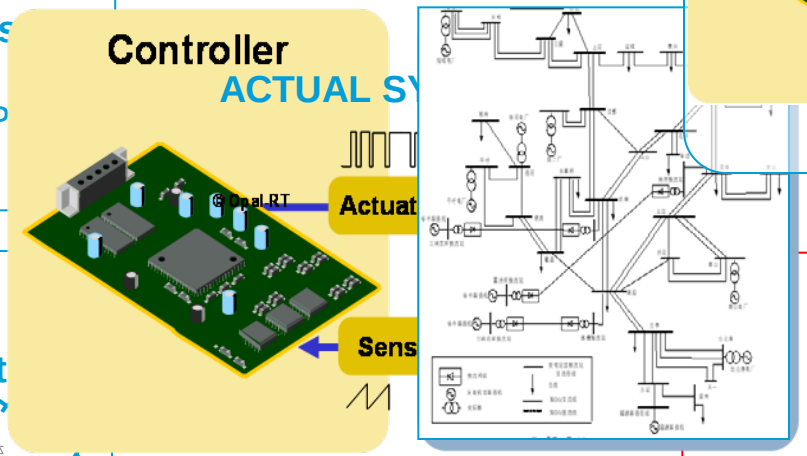
FINAL INTEGRATIONTESTS

5

HIL: Pre-production controller and Real-Time virtual plant

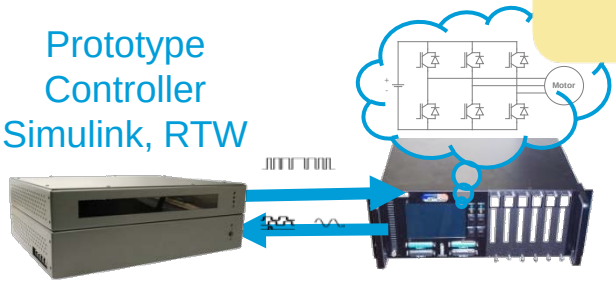


Real-Time Simulator



HIL and SIL: Control prototyping with Real-Time virtual plant

Prototype
Controller
Simulink, RTW



xPC, RT-LAB

Real-time PCs

Real-Time Simulator

MODEL BASED DESIGN

Iterative method

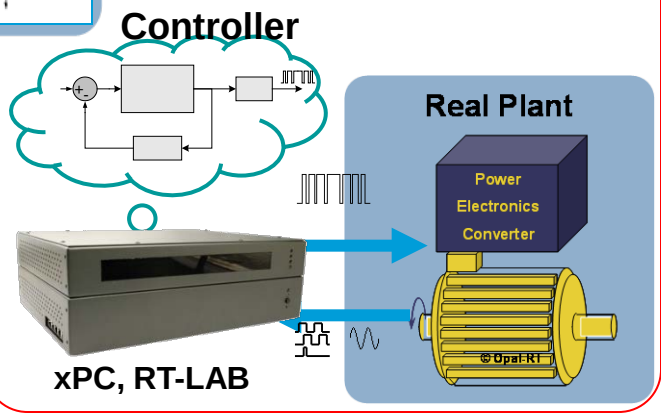
Refining specification and performance at each steps

Optimal use of simulation, HIL and physical prototype

3

4

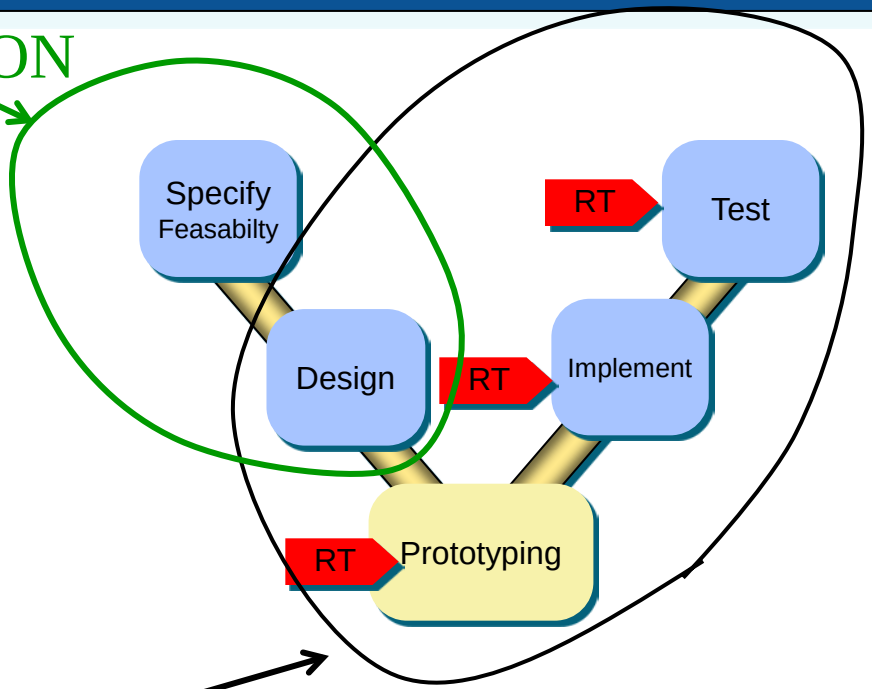
HIL-Control Prototyping with physical plant



xPC, RT-LAB

FAST OR REAL-TIME OPERATING MODES

- FAST PARALLEL SIMULATION
  – NON REAL-TIME
  - OPTIMISATION
  - RANDOM TESTS –
    Performance & Stress Analysis
  - SOFTWARE-IN-THE-LOOP
    - Control & Protection
    - Algorithm Test
  - PREPARATION FOR HIL TEST
  - With Normal PCs
    (Windows, LINUX or QNX)



- HARD REAL-TIME
  (LINUX or QNX RTOS)
  - DESIGN & OPTIMISATION
    - With Real Control & Protection Hardware
    - With Actual RT Software
  - RANDOM HIL TESTS
    - Performance, Stability
    - Controller Interaction
    - Stress Analysis
  - TROUBLESHOOTING & TRAINING
    - With Actual Control & Protection Hardware

Random Tests on Simple and Complex Networks

- To find Worst Case Scenarios or Statistical Distribution
  - Line Energization (3 breakers)
  - Fault + Line Reclosing (9 breakers)
  - Overvoltages and Arrester Energization

- Protection and Controls
  - Operating Times – Min, Max, Average
  - Test for Fault Operation
  - Controls – FACTS, HVDC, SVC, Series Capacitors …
  - Influence of System Transients
  - Harmonic Overvoltages and Inrush Currents
  - Stresses on Components
- Interactions between Distributed Control and Protection Functions
- WIDEBAND: Simultaneous Simulation of Very Slow (minutes) and Very Fast (nanoseconds) Transients
- BLACKOUT SIMULATION AND PREVENTION

Outline

- What is real-time simulation and HIL
- **Evolution of power systems**
- Evolution of real-time simulation technologies
- Type of simulation tools vs Application
- Challenges and solutions- Transmision system
- Adddtional challenges for Distribution and micro-grids

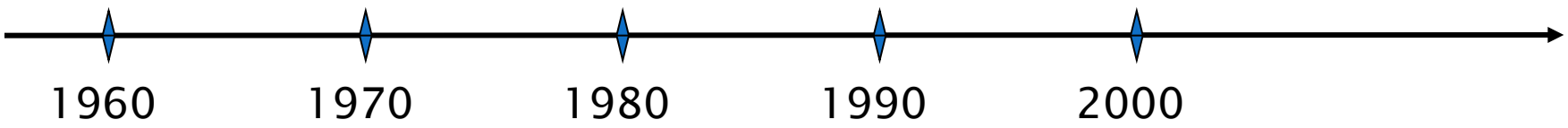
Challenges: More Complex Power Grids

Conventional AC Power Transmission Systems

HVDC, SVC & Thyristor-based FACTS

IGBT-based FACTS and HVDC

More Complex Systems
More and Faster Power Electronic Systems
(MORE NUMERICAL CONTROLLERS)



Challenges: More Complex Power Grids

Conventional AC Power Transmission Systems

HVDC, SVC & Thyristor-based FACTS

IGBT-based FACTS and HVDC

More Complex Systems
More and Faster Power Electronic Systems
(MORE NUMERICAL CONTROLLERS)

INTELLIGENT POWER GRIDS

- Distributed Generation and Controls
- Global Power Grid Control
- More Complex Protection Systems
- Integration made by several manufacturers
- Utilities have less control over the system

New <Smart> Distrisbution systems

Drives, Active Loads, FACTS

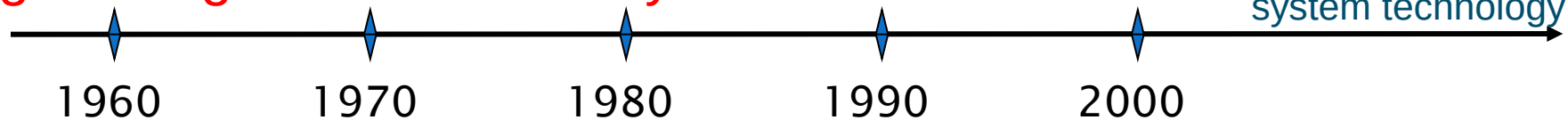
Wind farms

Micro Grids, distributed generation

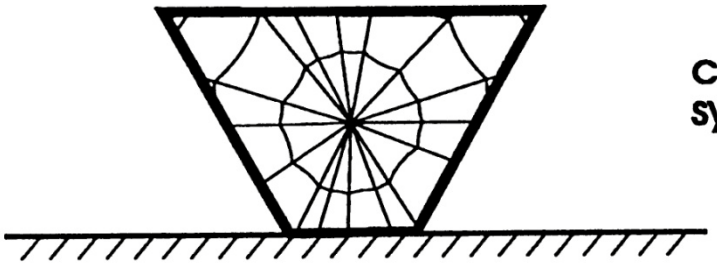
Plug-in & Electric Vehicles

Distribution systems are becoming more complex than high-voltage transmission systems

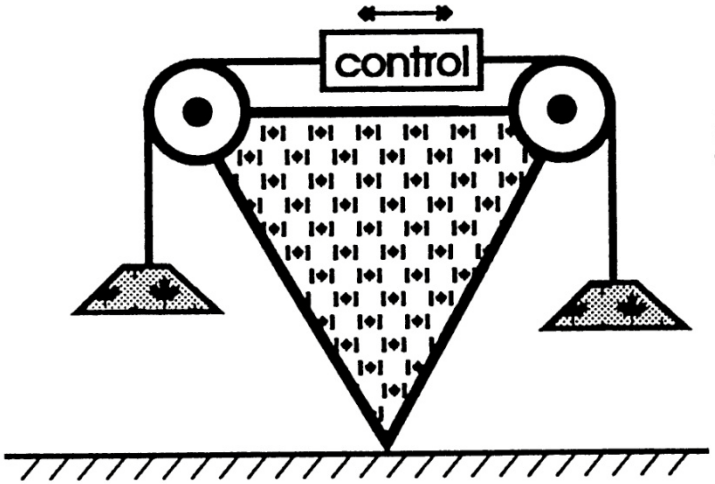
Fast and Real-Time simulators will become more important and must evolve with power system technology



Power systems are becoming increasingly dependent on complex control techniques to ensure efficiency, security and reliability



conventional system



modern and future systems

Outline

- What is real-time simulation and HIL
- Evolution of power systems

- **Evolution of real-time simulation technologies**

- Type of simulation tools vs Application
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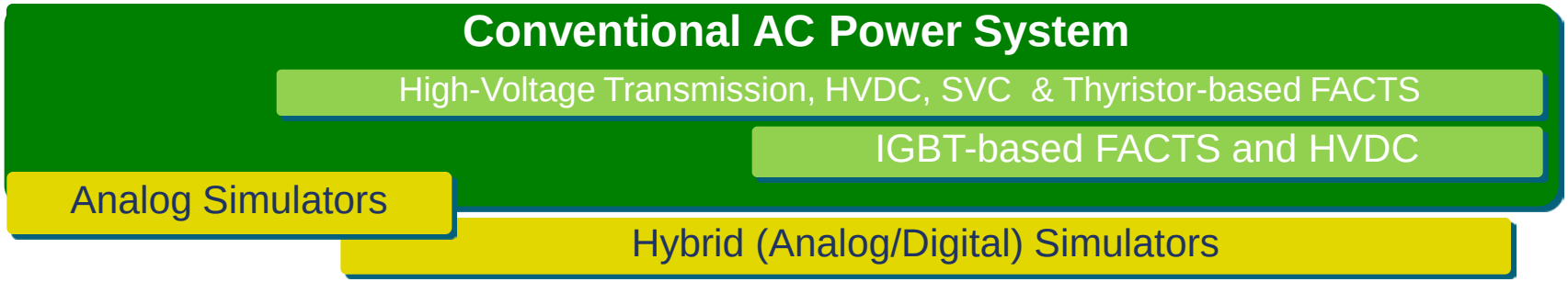
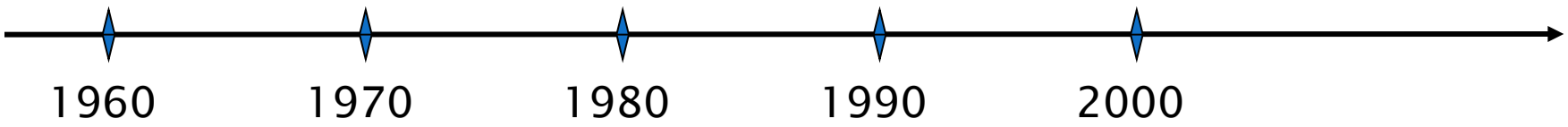
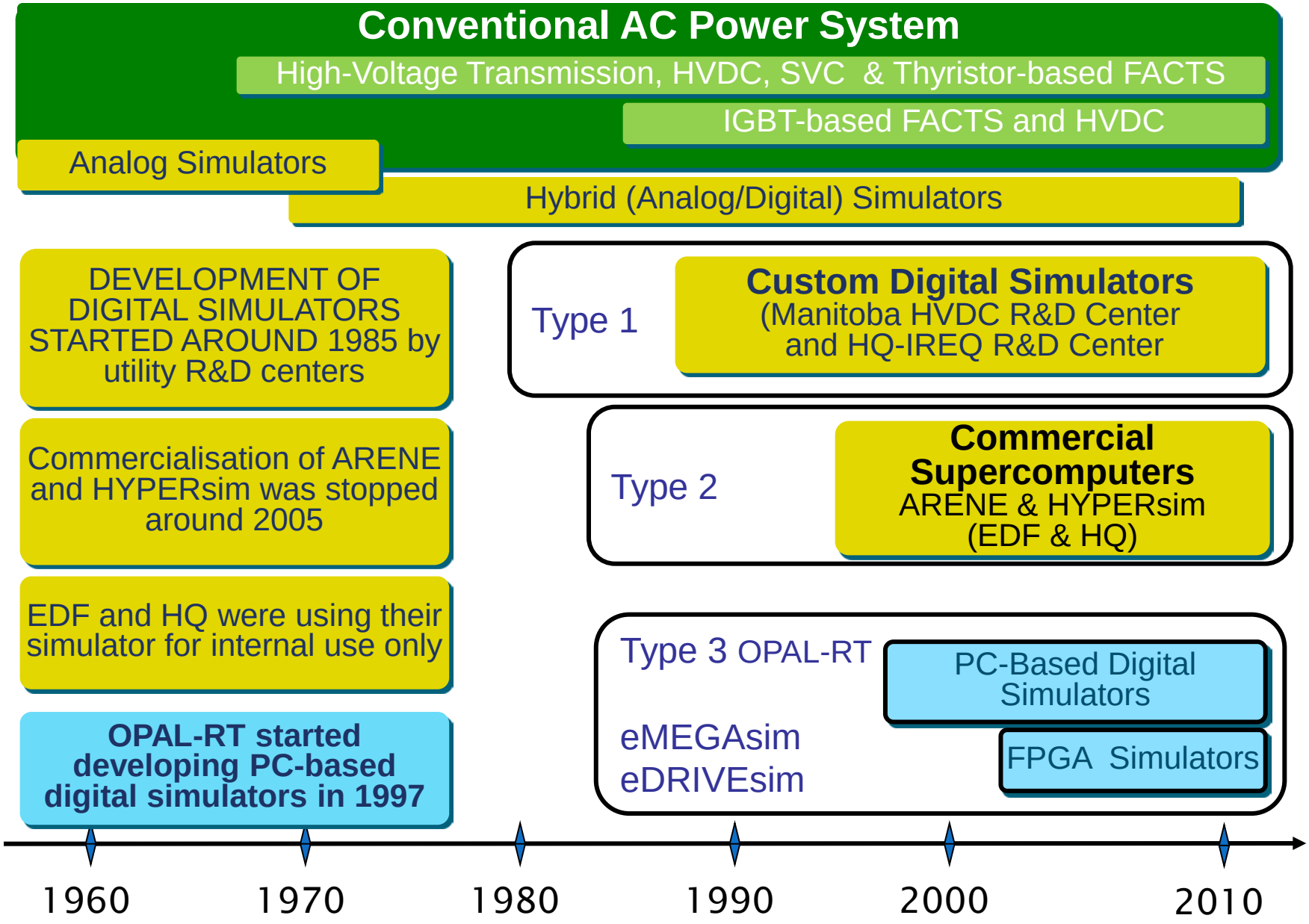
Evolution of Real-Time Electric Simulator Technology

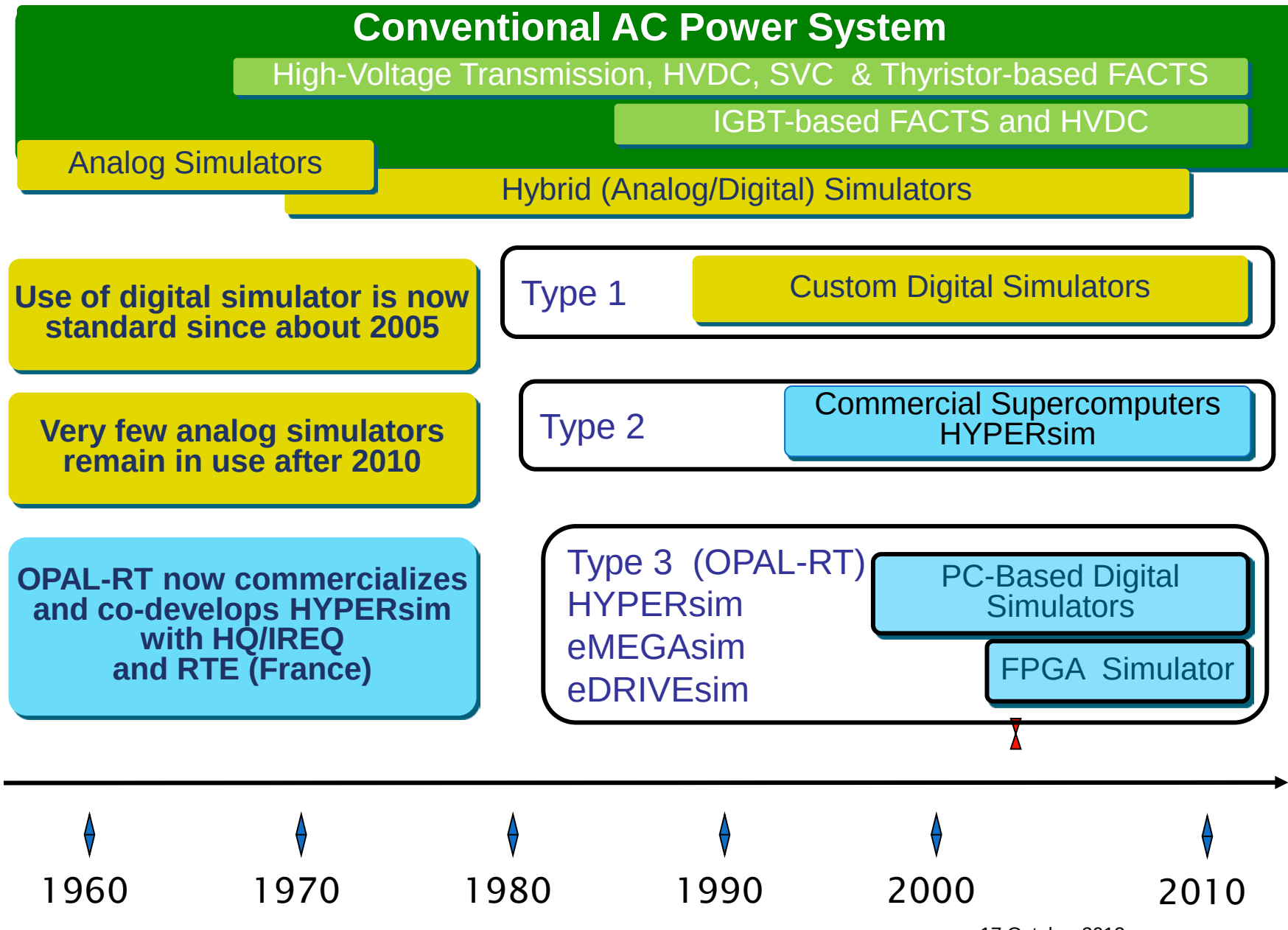




Evolution of Real-Time Electric Simulator Technology



Evolution of Real-Time Electric Simulator Technology



New Challenges for Real-Time Digital Simulators

Conventional AC Power System

High-Voltage Transmission, HVDC, SVC & Thyristor-based FACTS

IGBT-based FACTS and HVDC

New <Smart> Distrisbution systems

Drives, Active Loads, FACTS, MMC for Grids and Drives

Plug-in Hybrid Vehicles

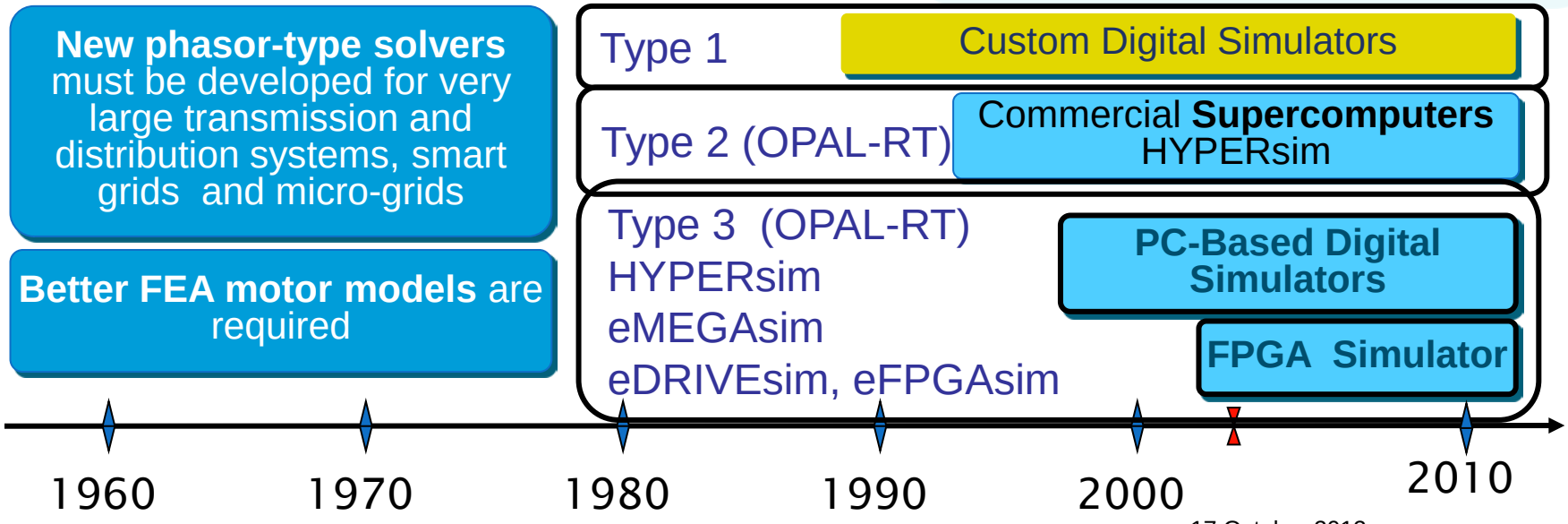
Micro-Grids Wind farms

Very fast and multi-level power electronic converters now require **FPGA-based HIL simulators with sub-microsecond time step**

New solvers must be developed to facilitate the use of FPGA chips

New phasor-type solvers must be developed for very large transmission and distribution systems, smart grids and micro-grids

Better FEA motor models are required



Simulator flexibility and performance must evolve faster than Power System Complexity Increases

Better Accuracy

- Increase Simulator bandwidth
- Smaller time step values
- Better models and validation

From Nanoseconds to Seconds
in the same simulation run

Better Scalability and Flexibility

- Transmission system with 1000 + nodes
- Distribution systems with 100,000 + nodes
- DC Grids, Several MMC HVDC with 1000 + cells
- Windfarms, PE, Plug-in …
- Phasor and EMT solvers

From Large Interconnected Grids
To Micro Grids to
To Small isolated systems

Better Affordability and Upgradability

- Commercial Off-The-Self High-End Computers
- Taking advantage of latest technologies
- developped for the web, mobile equipment and multi-media markets

Challenges: Better Accuracy, Scalability, Flexibility and Affordability are Requested by all Industries

From
Large Interconnected Grids
To Small isolated systems
To Micro Grids

Power Systems
- ❖Generation, transmission and distribution
- ❖Micro grids and distributed/renewable energy systems

Automotive
- ❖Hybrid electric vehicles
- ❖Plug-in hybrid and full electric vehicle

Electrical Trains and Ships
- ❖Multi-drive propulsion systems
- ❖Redundant distributed generation, load and distribution systems
- ❖Interconection with grids

From Seconds to Nanoseconds

Aircrafts
- ❖<more> and <all> electrical aircrafts
- ❖Redundant and very fast power eletronic

Serving all markets is a key advantage for OPAL-RT and its customers

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- **Type of simulation tools vs Application**
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Applications vs. Simulator Performance Requirements

Number of CPU

100

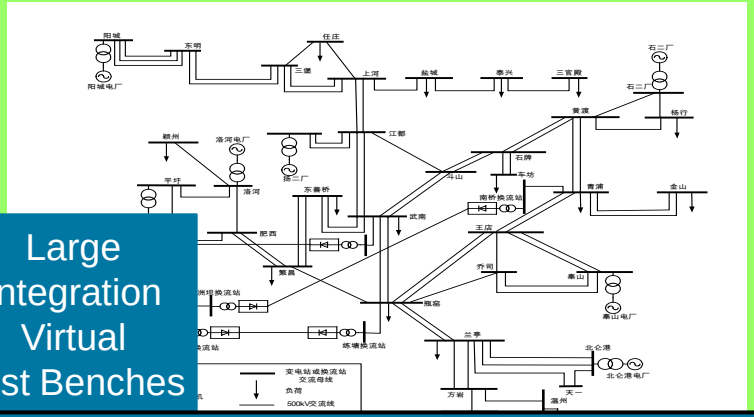
20

8

4

2

1



Large Power Grids,
HVDC, FACTS
Smart Grids, distributed Generation,
Renewable Energy
<Multi-domain
Real-Time Simulation>

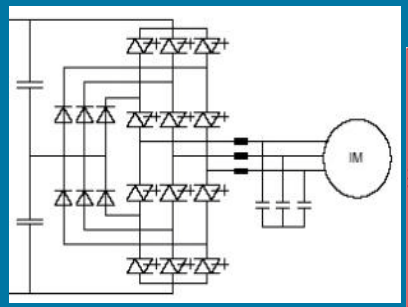
Large Integration Virtual Test Benches

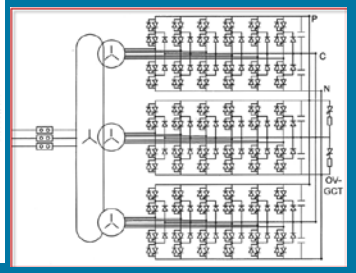
Power Electronic and Mechatronic Systems

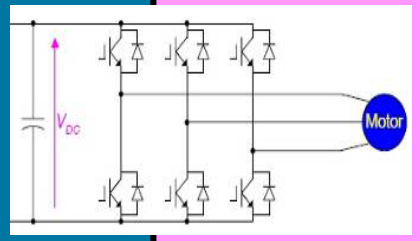
Very fast and low-latency power electronics

Mechatronics
Automobiles
Space

Ship, Trains, Industries
Power Grids





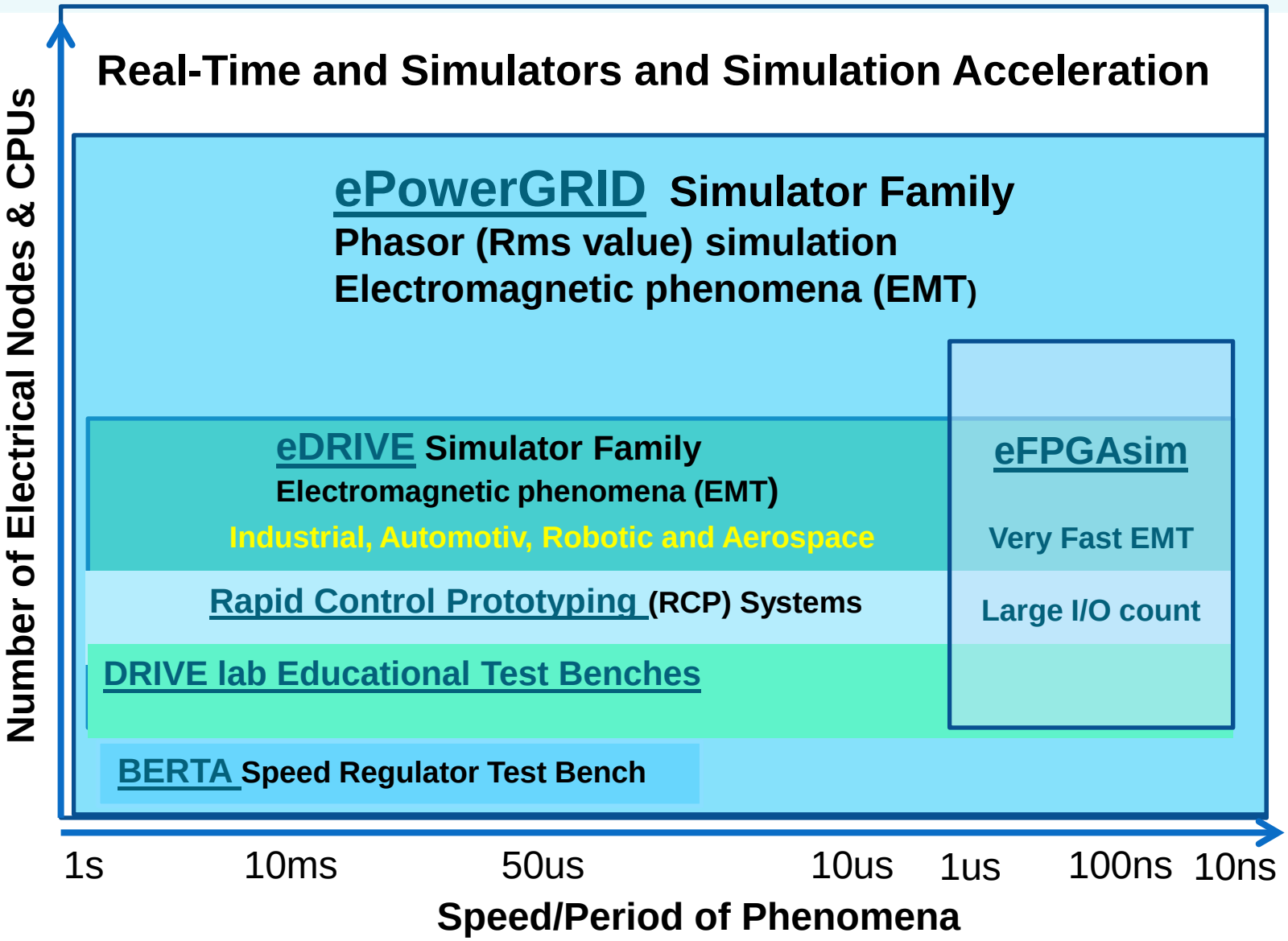


100 Hz	1 kHz	10 kHz	20 KHz	40 kHz	100 kHz	250 kHz	1 MHz	10 MHz
10ms	1 ms	100 us	50 us	25 us	10 us	5 us	1us	100 ns

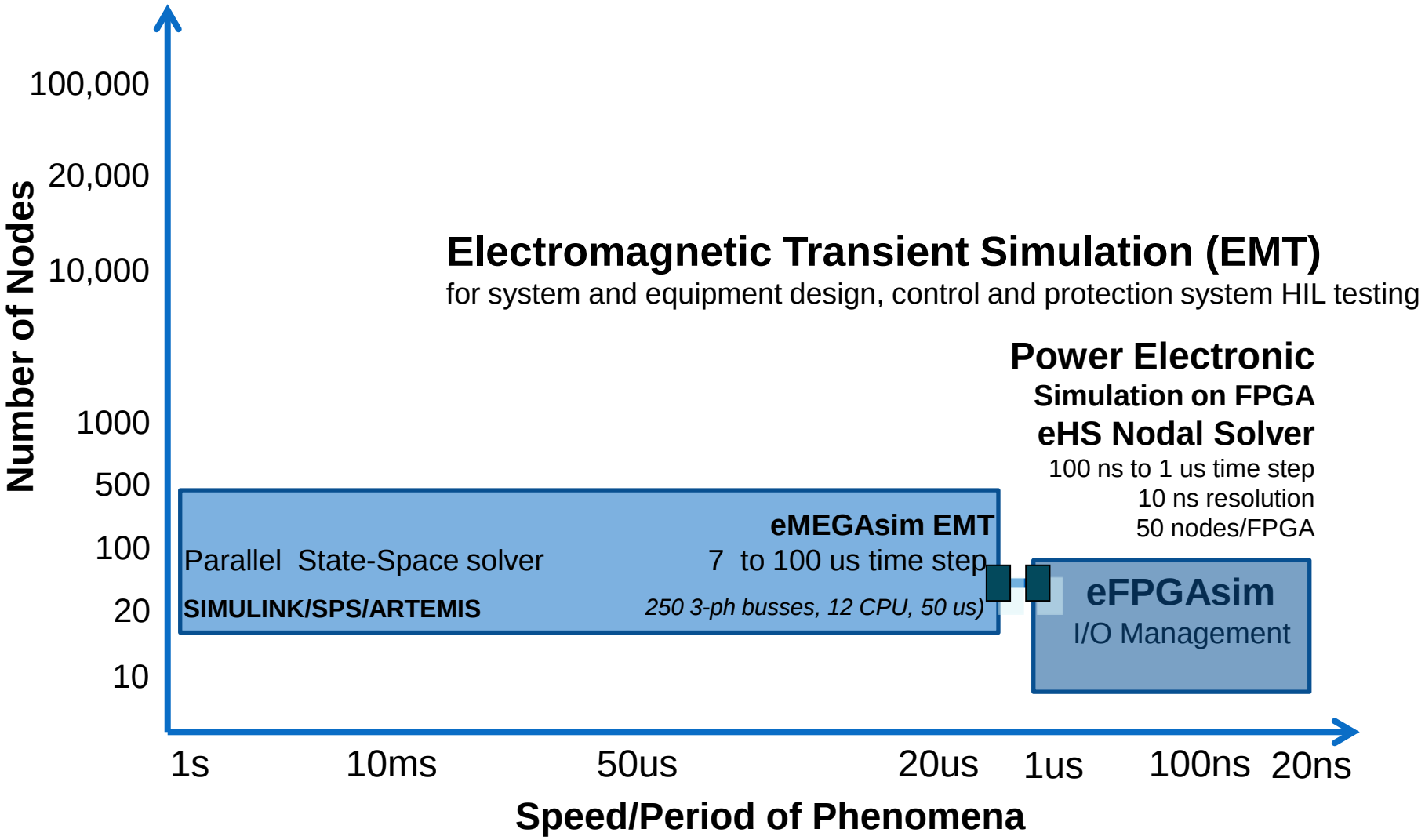
Slow Dynamics	Medium to Fast Dynamics & Transients	Very Fast Transients	Ultra- fast Transients

Model Sampling Rate and Time Step Requirement
(when OPAL-RT interpolation algorithm is used)

Solutions For Electrical System Simulation



ePowerGRIDsim Product Family Overview



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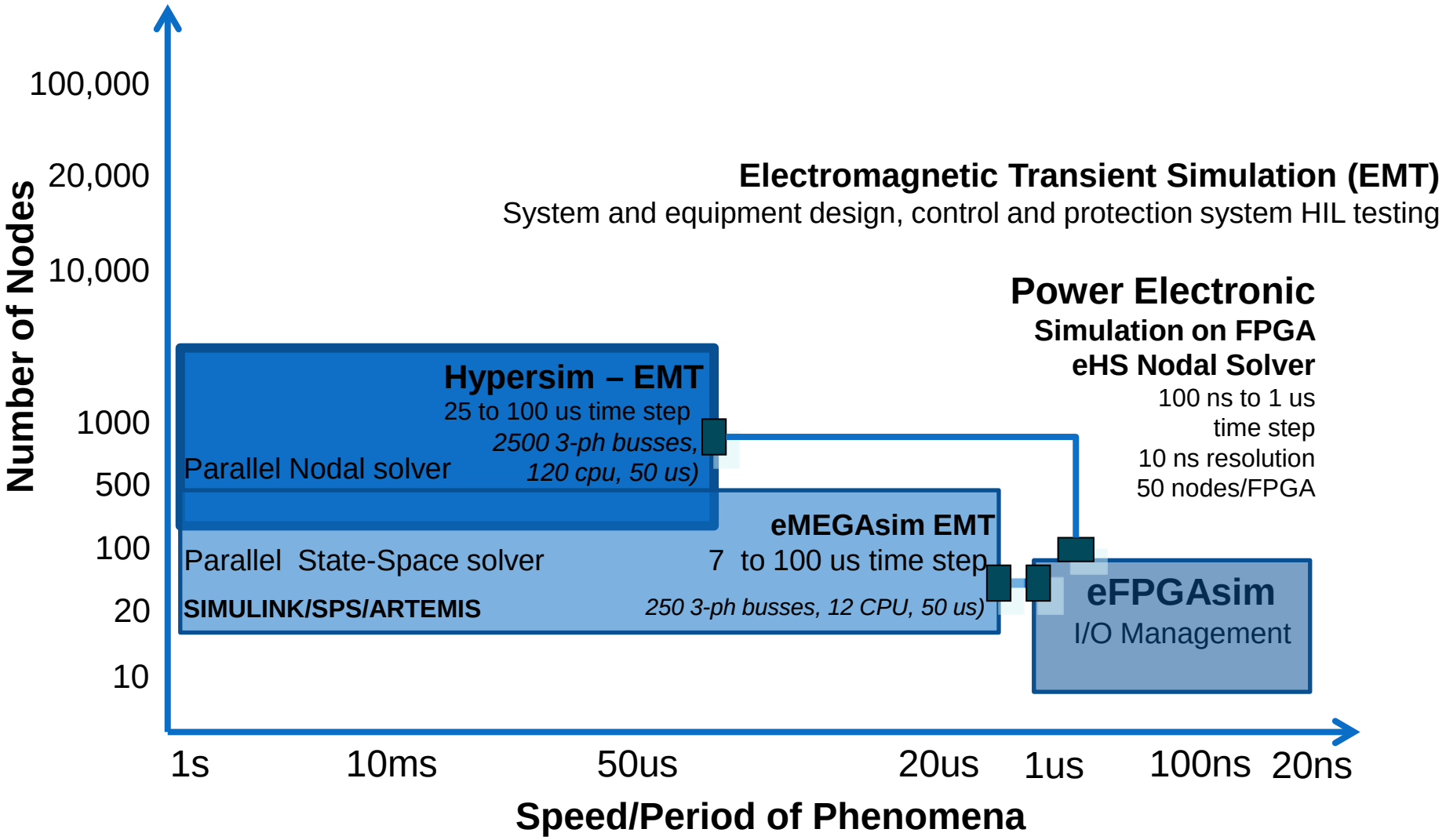
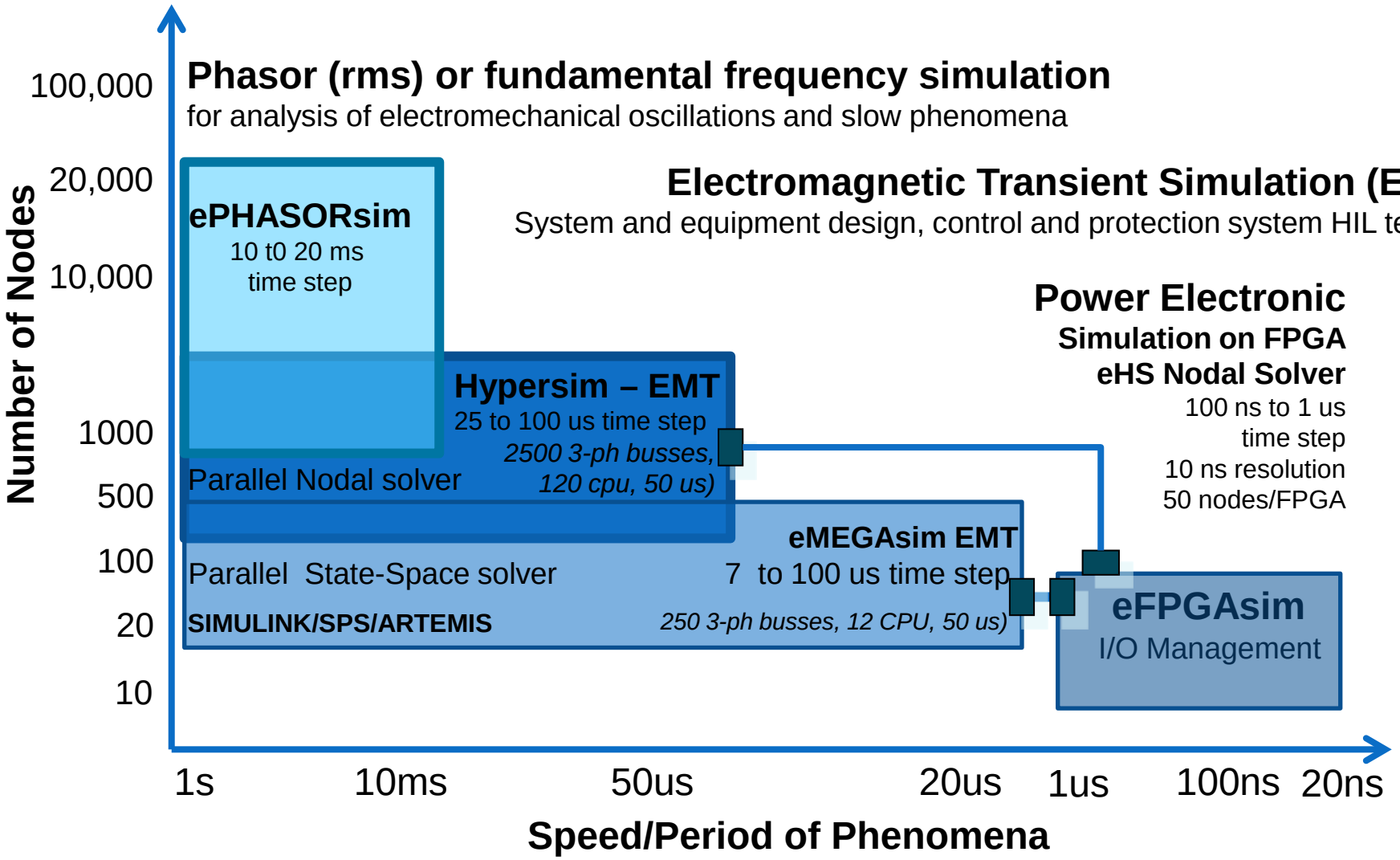
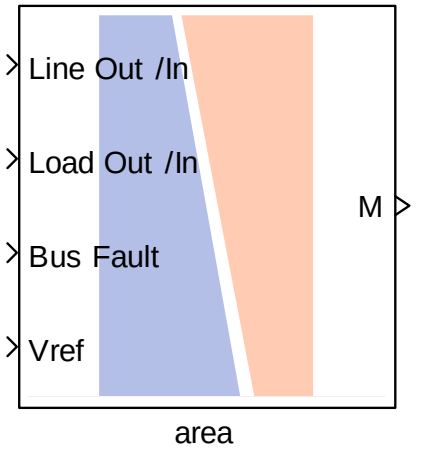


ePowerGRID Simulator Product Family



ePHASORsim

- **Real-time transient stability simulation tool**
  - for large-scale power systems
  - Phasor-domain solution with a time-step in the range of few milliseconds
  - 20,000 nodes – real-time - 10 millis
  - 5000 nodes with breaker switching
- **TRANSMISSION SYSTEMS: Positive sequence**
- **DISTRIBUTION SYSTEMS: Unbalanced systems** (2012Q4)
- Standard and extensible library
- Ideal for simulating several types of events, control, and adjustment actions
- Advanced HIL and Model-In-the-Loop testing of power system components
- Interfaced with SIMULINK



ePHASORsim Applications

- Integration sudies of distributed energy resources and loads
- Operator Training Simulator (OTS)
- Dynamic Security Assessment (DSA)
- Test, tune, and optimize setting of control devices
- Test SCADA systems with PMU measurements
- Test and adjustment local control systems such as transformer tap-changer, capacitor banks

HYPERsim: the Next Level of Scalability

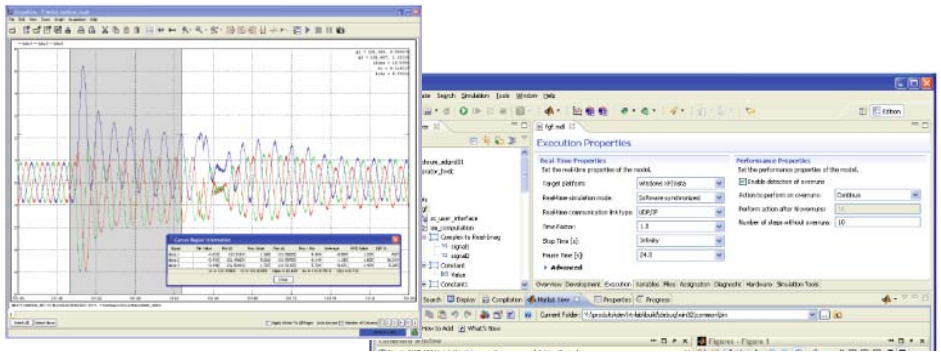
- SGI Global memory super computer
- Scalable to more than 1000 processors
- Fully Automatic allocation of processors base on analysis of the circuit diagram
- No modification of the model when I/O or the number of processors are modified
- Automated tests for protection and control testing
- RLC circuit parameter values can be changed on-the-fly without model recompiling
- Developed and used by Hydro-Quebec over the last 25 years; selected by major utilities and R&D center
- Will soon be integraded with OPAL-RT O7000 FPGA-based I/O, eFPGAsim simulator and Standard INTEL multi-core computer systems

eMEGAsim: Openess, Performance and Scalability

- **OPEN, HIGH-PERFORMANCE AND SCALABLE HARDWARE**
  - Standard INTEL LINUX Multi-Core Computers
  - Cluster with low-latency DOLPHIN switch
  - SGI Global memory super computer
  - OP5600 and OP7000 Multi-FPGA systems
- **OPEN SOFTWARE**
  - RT-LAB Distributed Real-Time Framework
  - Full integration with MATLAB, SIMULINK, RTW, SimPowerSystem and SimScape
  - ARTEMIS, SSN and eHS-FPGA solvers
- **TEST AUTOMATION**
  - TestStand, Phython script, MATLAB Script

- Used by major manufacturers, Universities and R&D centers since more than 7 years

OP5600 eDRIVEsim HIL System



Infolytica and JMAG
FEA-Based Motor Models

Controller under test

OP5600 HILBOX with 2 to 12 CPU cores, SPARTAN 3 or VIRTEX-6 XILINX FPGA

eDRIVEsim: Optimized for Power Electronic HIL

- **AFFORDABLE SCALABLE ENTRY-LEVEL HIL SYSTEMS**
- **OPEN SOFTWARE**
  - RT-LAB Distributed Real-Time Framework
  - Full integration with MATLAB, SIMULINK, RTW, SimPowerSystem and SimScape, JMAG and Infolytica FEA motor models
  - ARTEMIS, SSN and eHS-FPGA solvers
  - Library of demo and models for power electronic
  - Upgradeable to eMEGAsim

- **OPEN AND HIGH-PERFORMANCE HARDWARE**
  - Standard INTEL LINUX Multi-Core Computers
  - OP5600 and OP7000 Multi-FPGA systems
- **TEST AUTOMATION**
  - TestStand, Phython script, MATLAB Script

- **Used by almost all major power electronic and hybrid vehicles manufacturers, Universities and R&D centers since more than 12 years**

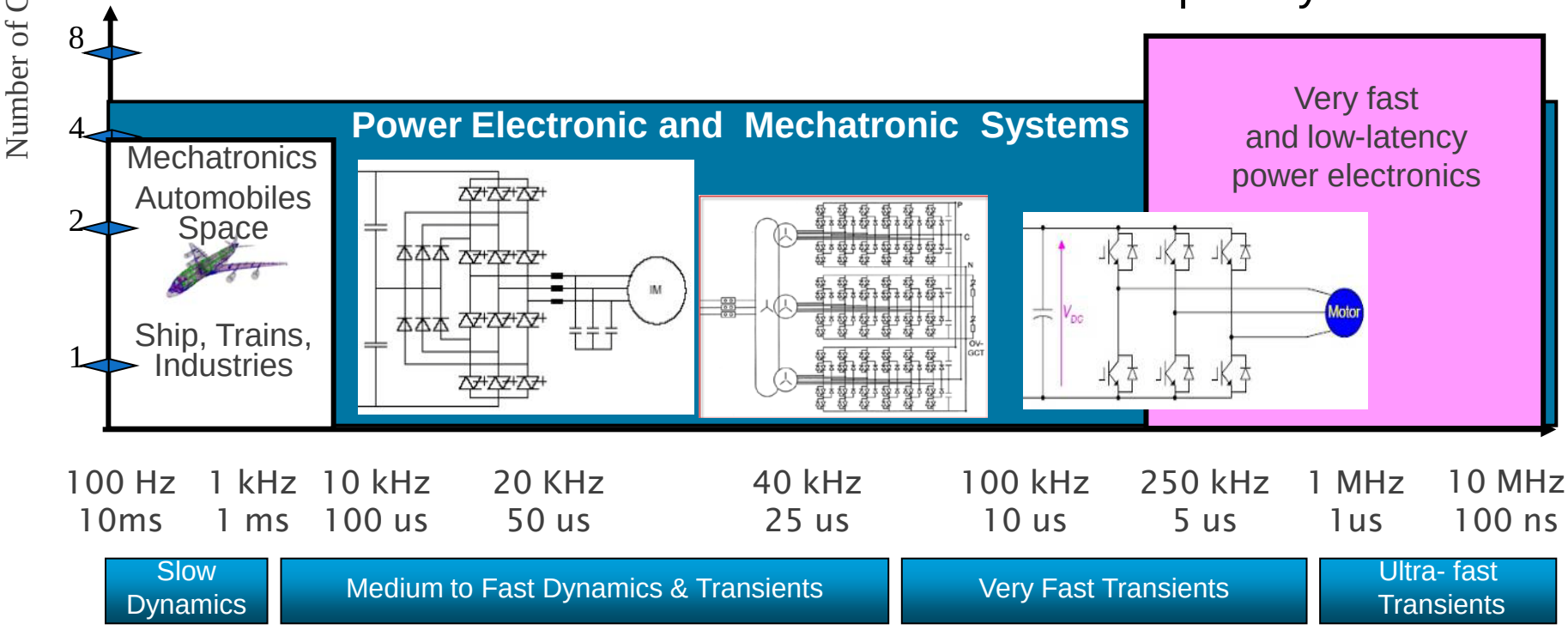
eDRIVEsim Applications

eDRIVEsim Series C: Simple Voltage Source converters HIL systems

eDRIVEsim Series D: AC Fed Converters HIL systems

Finite element based motor models (**Infolytica and JMAG**)

eHS FPGA Electrical Solver with fault simulation capability



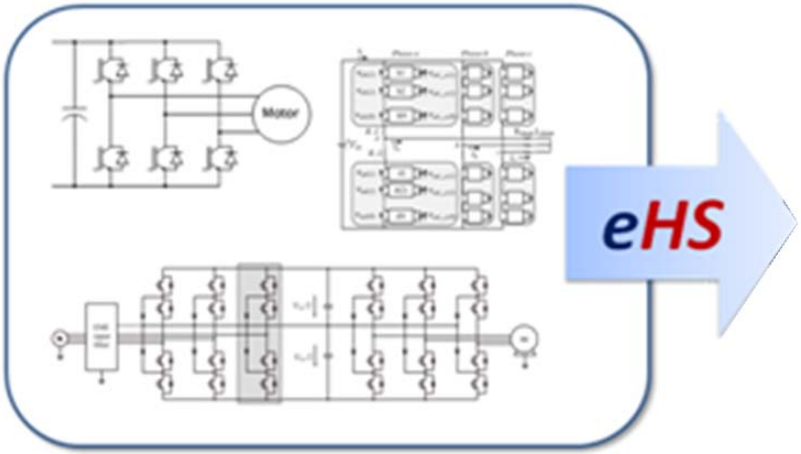
Model Sampling Rate and Time Step Requirement
(when OPAL-RT interpolation algorithm is used)

eFPGAsim and eHS Electrical Solver

Power Electronics Simulation on FPGA Made Easy

MATLAB SIMULINK

SPICE



FPGA

- From Simulink/PLECS to FPGA in a few seconds
- Change topology and parameters on the fly
- No compilation required
- No complex VHDL coding required

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- **Simulator Hardware PLateforms**

- Challenges and solutions- Transmision systems
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HARDWARE PLATE FORM

HYPERSIM

Silicon Graphic UV-10 super computer 8 to 256 cores or more
40 CPU Core per 4U chassis

Can be interfaced with several OP7000 multi-FPGA and I/O systems

More …

eMEGAsim

eDRIVEsim

OP5600 4- to 12-CPU core computer integrated with one FPGA and I/O system – 4-U chassis
Up to 256 I/O converters per system
Several OP5600 can be interfaced with PCI Express DOLPHIN links

More …

eMEGAsim

FPGA & I/O Systems

OP7000 Multi-FPGA and I/O system – 6U Chassis
Up to 9 VIRTEX 6 FPGA and 256 I/O converter per system and signal conditioning boards
Can be interfaced with the OP5600, standard computer chassis or with the SGI UV 10 super Computer

More …

Image
4U 12-Core computer

eMEGAsim

eDRIVEsim

4-U Computer system with 4 to 12 processor core and PCI Express link to interface with OP7000 system

More …

OP7010 Portable Test System – EDF Nuclear Station

Delivered – Sept 2011

5 to 15 units to be delivered as standard test systems…

Two High-end Hardware Computer Plateforms with Integrated I/O and FPGA

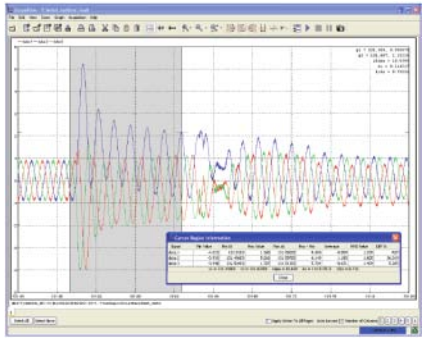
OP7000 Multi-FPGA System

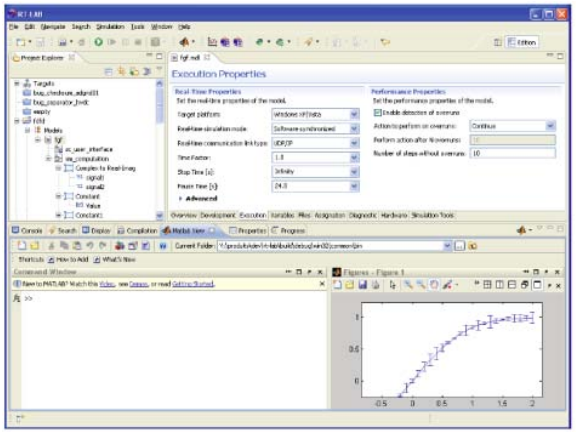
Up to 9 VIRTEX 6
256 I/O with signal conditioning

OP5600 HILBOX Chassis

Up to 12 CPU Cores
256 I/O
One SPARTAN3 or VIRTEX 6 FPGA

OP5600 HIL Box – eMEGAsim and eDRIVEsim

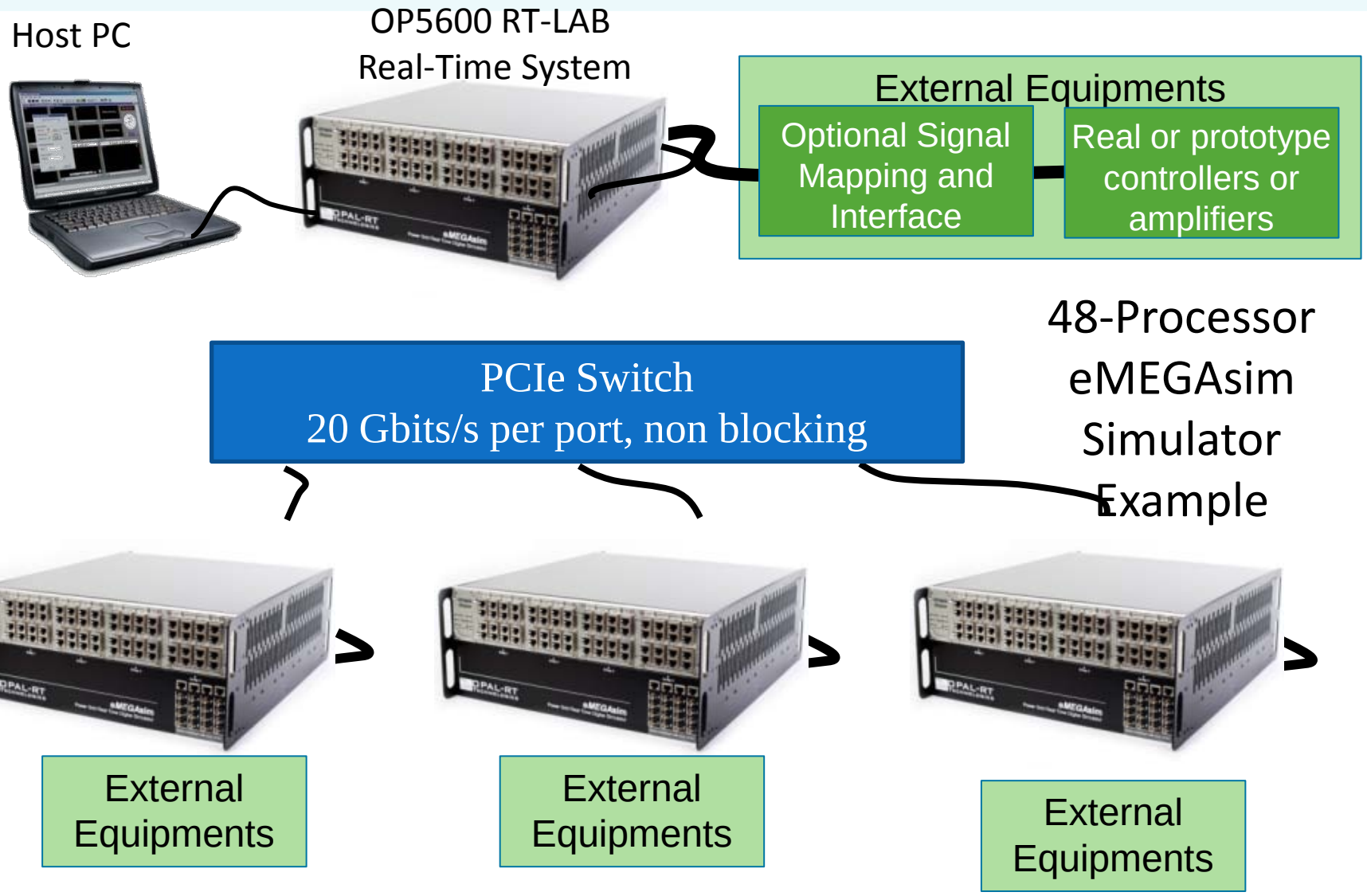




OP5600 HILBOX

Will soon be compatible with HYPERsim

OP5600 Scalability: Large Number of Processors



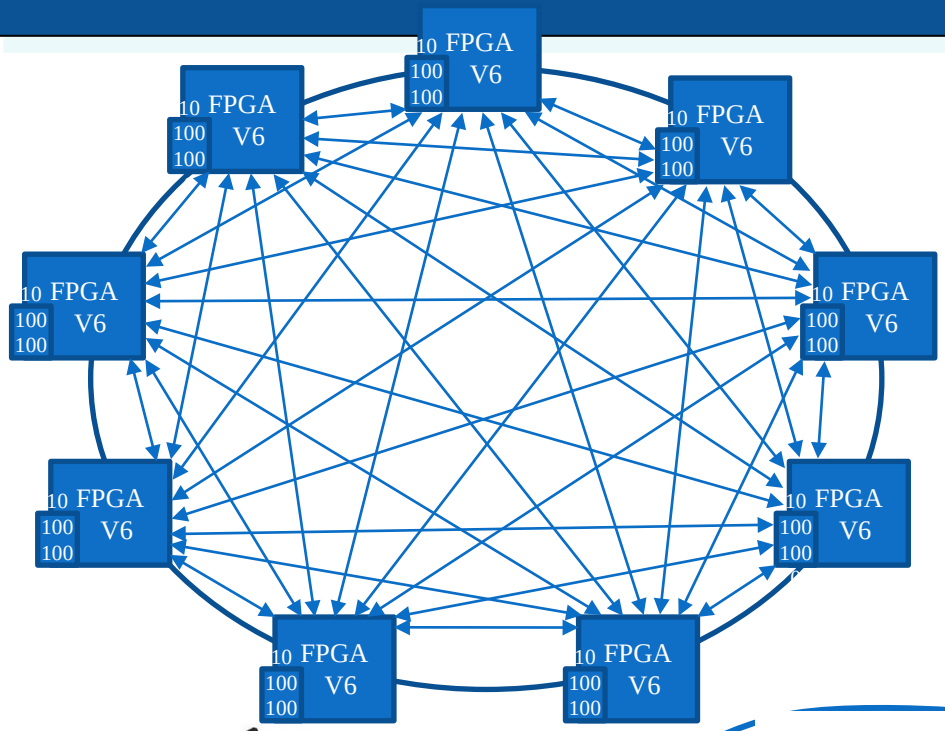
Compatible with eMEGAsim and will soon be compatible with HYPERsim

OP7000 – eFPGA MULTI-FPGA SIMULATOR AND I/O SYSTEM

eFPGAsim - OP7000 Multi-FPGA Simulation Hardware

Interconnected with eDRIVEsim, eMEGAsim and will soon with HYPERsim

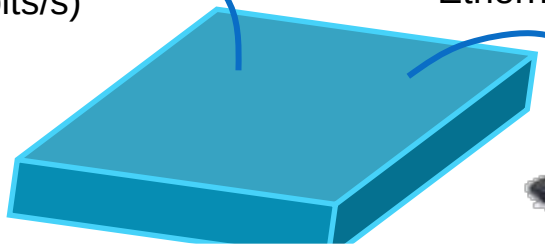
OP7000 Hardware Architecture – Multi-FPGA



- Interconnected power electronic model and cntroller
- eHS Electrical FPGA solver
- User developed controllers using XILINX-SIMULINK System Generator
- Interfaced with Simulink models running on INTEL CPU cores with PCI Expess x4 link
- Interfaced with external hardware

OP7000 FPGA Based I/O System
(A/D, D/A, DIO, Virtex 6 FPGA)

PCI Express
4x5Gbits/s)



Standard Real-Time Computer
(1, 2, 3 , 4U)
(LINUX, 2 to 12 processor cores)

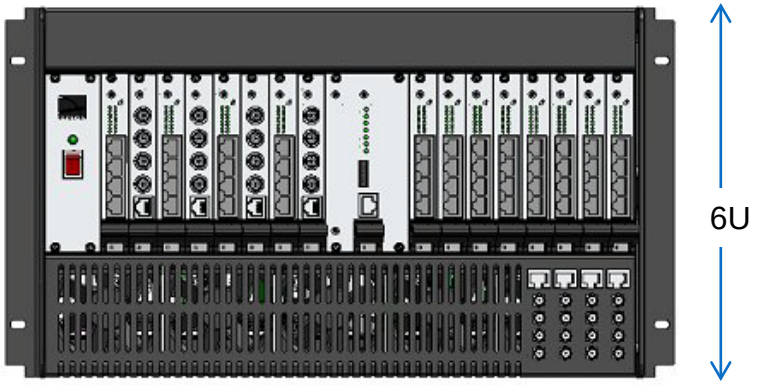
Ethernet

Standard Windows
Host Station

OP7000 – 6U and 2U Chassis Formats

OP7010 – Full Size 6U chassis
(available since Sept 2011)

-One to nine VIRTEX-6 FPGA, up to 256 I/O ch.
-One PCI Express x4 link (xx20Gbits/s) to interface with real-time multi-core PCs



❖One PCI Express x4 link (xx20Gbits/s) to interface with real-time multi-core PCs

❖ Optimized for application with several conventional I/O channels (up to 256 ch)
❖Integrated signal conditioning (back-side I/O board)
❖Integrated signa monitoting (front side)
❖Or up to 256 low-speed (<150 Mbits/s optical fibers

❖One fast Aurora 5-Gbits/s link is used to interface each FPGA

OP702x – Compact 2U chassis (2012Q4)

-One VIRTEX-6 FPGA, up 16 5-Gbit/s optical fibers
-One PCI Express x4 link (xx20Gbits/s) to interface with real-time multi-core PCs

OP7020 -6– with ML605 XILINX VIRTEX 6, 8 SFP transceivers (Oct 2012)
OP7020-7 – with ML70x XILINX VIRTEX 7, 16 SFP transceivers (2012Q4)
OP7021-6/7 – with VIRTEX 6 or7, 8 to 16 SFP and IOs (2012Q4)

-4, 8 or 12 pairs of fast optical transceivers
- SFP format, 1 to 5 Gbits/s

❖ Optimized for applications with high-speed optical fibers, SFP format
❖ Typical applications are the interface with HVDC MMC controllers and MMC control prototyping system

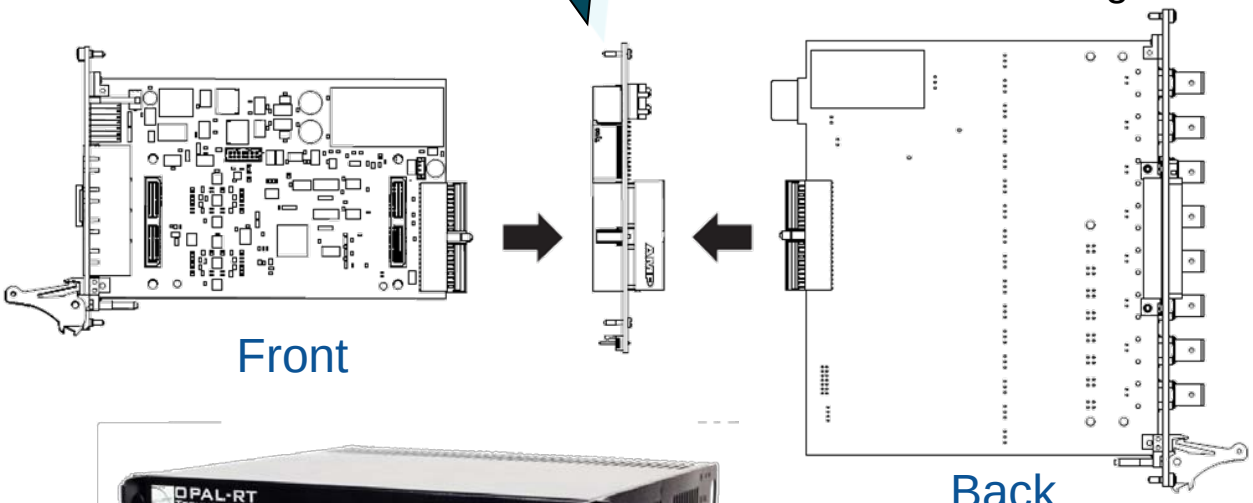
❖ Compatible with XILINX ML VIRTEX 6 (now) and VIRTEX 7 (2013Q1) boards

OP7010 Hardware Architecture – I/0

Inter-FPGA Communication Backplane

I/O Carrier or Virtex 6 FPGA Module

Integrated Signal Conditioning



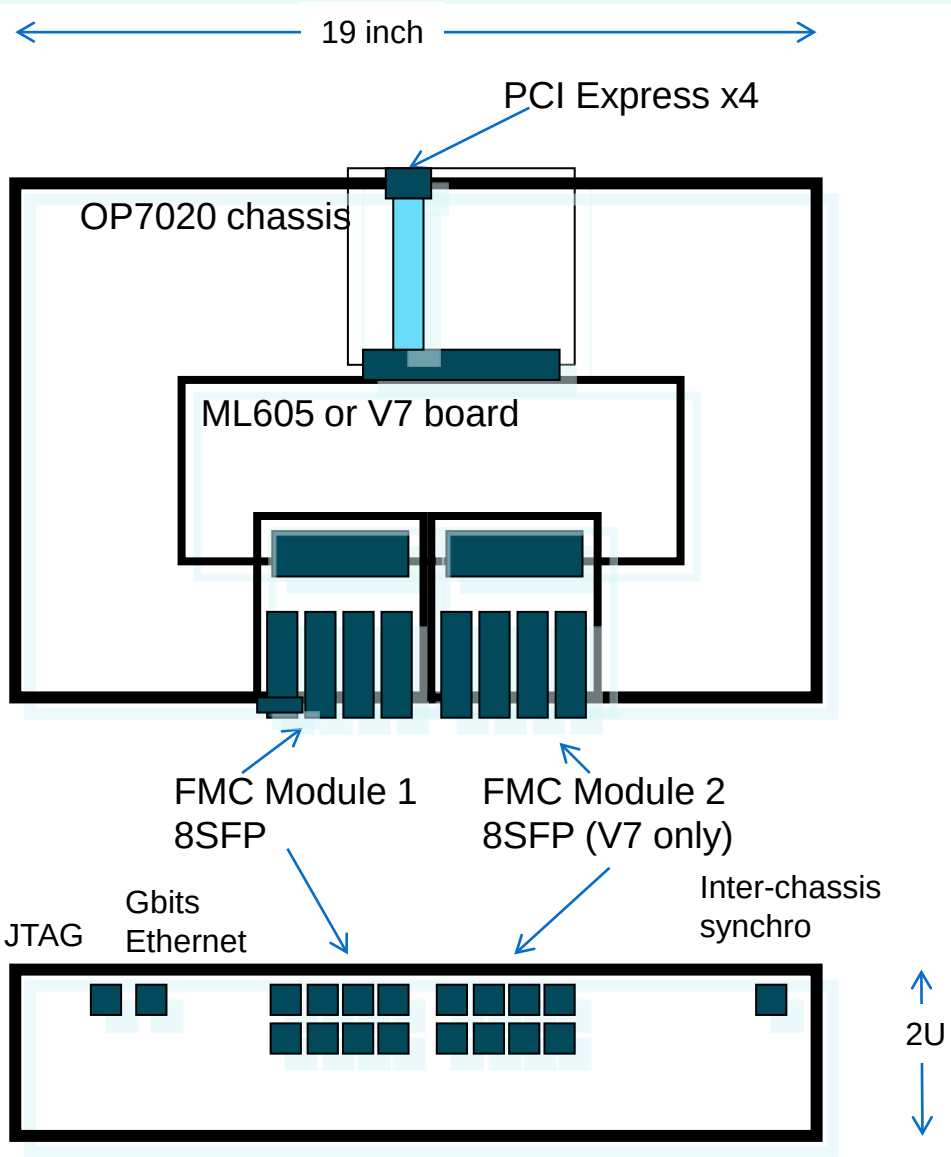
Front

Back

- Optical fiber
- Digital Input/Output
- Analog Input/Output
- Current Outputs

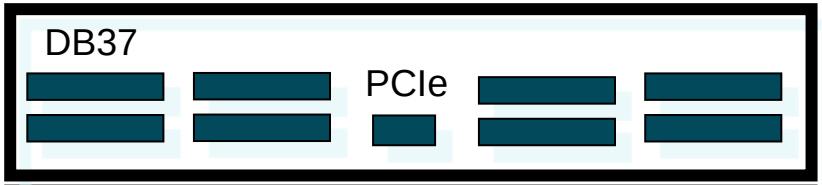
Up to 9 FPGAs!

OP7020 Hardware Architecture – I/0



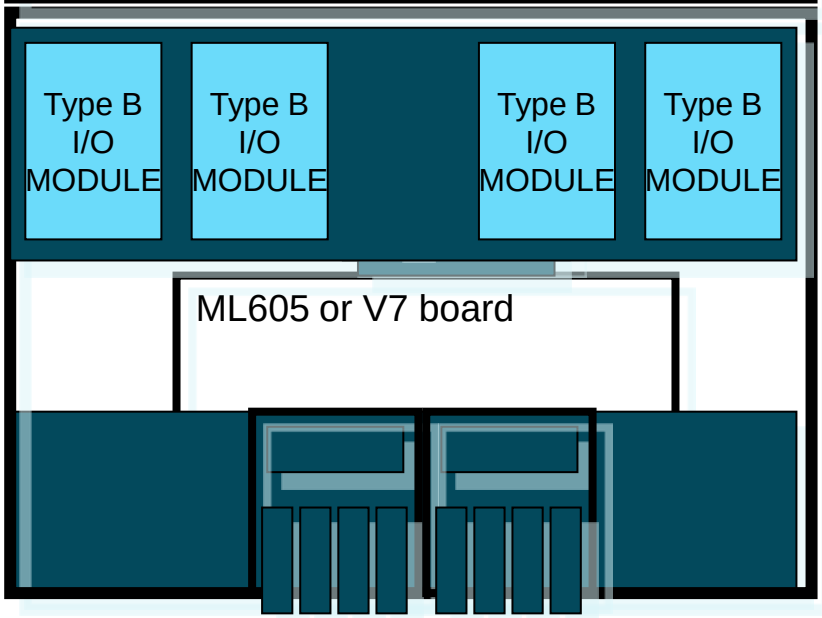
OP7021 Hardware Architecture – I/0

Rear view



8 DB 37 connector
16 ch. Per connector
2 pins per ch

OP7021 chassis
Top view



Carrier noard with 4 Type B IO Module
16 ch per Analog module (A#D or D/A)
32 ch per DIO module (DI or DO)

Carrier board with
32 Fast DI ch. RS422, or TTL 5-126V
32 Fast DO ch 5V-16V FET

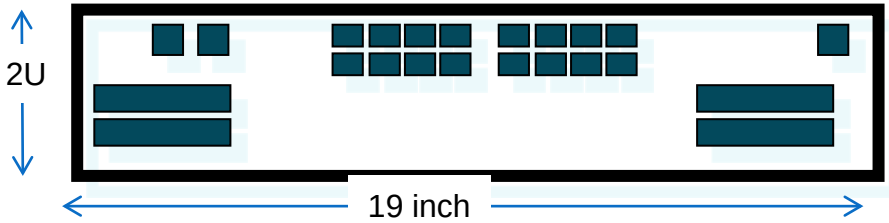
FMC Modules
8SFP + 8 SFP

JTAG

Gbits Ethernet

Inter-chassis synchro

Front view



4 DB 37 connector
16 ch. Per connector
2 pins per ch

Outline

- What is real-time simulation and HIL
- Evolution of power systems
- Evolution of real-time simulation technologies
- Type of simulation tools vs Application

- **Challenges and solutions- Transmision systems**

- Adddtional challenges for Distribution and micro-grids

CHALLENGES & SOLUTIONS -OPENEES

- **Scalability** to simulate very large systems
  - 250 3-phase busses on one PC! - eMEGAsim
  - 1000 busses on SGI- HYPERsim
  - 1500 MMC cells in one FPGA chip
- Fast and low latency inter-processor communication
  - MULTI-CORE CPU
  - Cluster of 8-CPU Super-computers
  - PCI Express switches for clusters
  - Multi-FPGA s - OP7000 eFPGAsim

- **Easy** management of parallel simulation
- Automatic CPU allocation -HYPERsim

- **Precise and stable** network solver
- ARTEMiS L-STABLE ORDER 5 SOLVER
- SSN Solver and FEA for motors

- Fast and **low latency Ios**
- **Very small time step simulation**
- FPGA (250 nanosecond time step)

- **Easy use of FPGA chips** for fast power electronic simulation
- eHS Nodal FPGA Solver
- No bit stream generation
- Parameter and topology modified on the fly!

CHALLENGES & SOLUTIONS

- Simulation of IGBT switching
- Simulation of MANY IGBTs

- Interpolation (since 2000)
- Comparisons with analog set up
- Tests with hundreds of IGBT (MMC)
- 1500 MMC cells and 3000 swith in one FPGA chip
- Simulation on FPGA at 250 nanos

- **Technologies trusted** by large organizations

- MATLAB > 20 years, >1M users
- SPS> Hydro-Québec> 14 years
- HYPERsim HQ > 20 years
- OPAL-RT: 15 yrs experience,
- Advanced customers in all markets (aero, auto, power)

- **Affordability**

- From 25 k$ and up
- Price will go down with volume

Outline

- What is real-time simulation and HIL
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- **Adddtional challenges for Distribution and micro-grids**

CHALLENGES & SOLUTIONS FOR DISTRIBUTION SYSTEMS

Challenges	**EMT – Electromagnetic transient simulation DC to 10 kHz of large distribution systems integrated with power electronic systems (PV, plug-in hybrids …)**	
	Solutions – OPAL-RT	**Status – Sept 30, 2012**
Large number of **a) short-Lines** **b) nodes** **c) breakers** - Very short line sections between 100 m and 2 km. - Line travel time cannot be used to implement parallel simulation (1us = 300 m, 10 us = 3km, 50 us = 15 km !)	ARTEMIS SSN (2-Step solver)	Good, but not very scalable over 200 nodes (3 CPU) Optimization required
	Stub-lines	Good to increase number of nodes but parasitic capacitors are added, which decreases accuracy for low-load conditions
	New class of parallel EMT solvers	Not started at OPAL-RT We are not aware of new advancement in this domaine

CHALLENGES & SOLUTIONS FOR DISTRIBUTION SYSTEMS

Challenges	EMT – Electromagnetic transient Cont'd	
	Solutions (OPAL-RT)	**Status (Sept 30, 2012)**
Large number of **a) short-Lines** **b) nodes** **c) breakers** - Very short line sections between 100 m and 2 km. - Line travel time cannot be used to implement parallel simulation (1us = 300 m, 10 us = 3km, 50 us = 15 km !)	Simulation on FPGA to decrease time step and then decrease innacuracies caused by artificial delays (Stub lines ...	- Tstep < 1us buts can be achieved
	eFPGAsim and eHS solver	Available but size is limited and programming complexity is large
	OP7000 Parallel FPGA solver	Under tests but complex programming
	New processor technologies	- ARM + FPGA (Started) - promising -Multi-core DSP (Started with a university) -GPGPU (promising but not yest available for low latency applications

CHALLENGES & SOLUTIONS FOR DISTRIBUTION SYSTEMS

Challenges	**Fundamental frequency only simulation of very large distribution systems** for protection and wide area control design and testing if low frequency resonnances (about 150 Hz to 10 kHz) can be neglected	
	Solution (Opal—RT Plan)	**Status (as of Sept 30, 2012)**
Large number of **a) short-Lines** **b) nodes (<5000)** **c) breakers**	- ePHASORsim Dist V1 beta - Unbalanced three-phase Phasor Solver (phase-by -hase solution) for te circuit - Dynamic models for machine, loads and controllers like in PSS/e	-Under test -Unbalanced -DNP3 Interface -Basic set of controller, OLTC, VVR -Basic machine - ZIP, constant I and P load models -Breakers and faults
		-Single processor -20,000 nodes, no breaker switching -5,000 nodes with breaker switching - first demo/proto planned for Oct 30

CHALLENGES & SOLUTIONS FOR DISTRIBUTION SYSTEMS

Challenges	Fundamental frequency only - Cont'd	
	Solution (Opal—RT Plan)	**Status (as of Sept 30, 2012)**
Large number of **a) short-Lines** **b) nodes (<5000)** **c) breakers**	Cont'd	
Islanded-mode conditions may lead to solver instability	May require -implicite solver with itteration -new load models -Ilanding mode detection	-Test cases to verify the stability of V1 will start in Oct 2012 - we will start to look for partners
Average power electronic system models		-Will start in 2013 depending on customer request -- technology well known (like PSS/e)

CHALLENGES & SOLUTIONS FOR DISTRIBUTION SYSTEMS

Challenges	Fundamental frequency only Extremely large network	
	Solution (Opal—RT Plan) Parallel Phasor Solver	Status (as of Sept 30, 2012)
Very large number of nodes (>100,000)	ePHASORsim Dist V2 Parallel phasor solver -option 1- SSN	- Basic algorithm tested with MATLAB -C Code must be implemented -Proto for April 2013
	GPGPU (General Purpose Graphical Processor Unit)	- dev started in year 2009 but on the ice -Dev will restart in 2013 based on V2 results
	- Look for partners making R&D for real-time and faster than real-time transient dynamic simulation	

CHALLENGES & SOLUTIONS FOR DISTRIBUTION SYSTEMS

Challenges	Detailled simulation of power electronic systems integrated with distribution systems w	
Mixed EMT-Phasor	Solution (Opal—RT Plan)	Status (as of Sept 30, 2012)
System with less than 200 nodes with detailled power electronic models	Full EMT solution with Combined CPU and FPGA	-Actual solution with eMEGAsim and eFPGAsim -Multi FPGA simulation under test
Systems with up to 2000 nodes in phasor mode with detailled subsytems simulatated with EMT mode and detailled power electronic model	Combined Phasor and EMT solver with SSN interface - Use of multi-port frequency domain equivalent at interconnection points	- easy for radial distribution system -Feasibility studied for meshed systems will started in 2013 **- looking for parnership**

CHALLENGES & SOLUTIONS FOR DISTRIBUTION SYSTEMS

Challenges:	**DATA MANAGEMENT & SYSTEM DIAGRAM** **Finding a common data based for all simulation tools (different types of simulation and different vendor tools**	
	Solution **(Opal—RT Plan)**	**Status** **(as of Sept 30, 2012)**
Interface between EMT tools and Phasor-type tools	Temporary solutions not realy integrated	-Simple CVS and EXEL files for ePHASORsim - interface with MATLAB file for EMT (SPS) - interface between EMTP-RV and HYPERSIM will be investigated in 2013 with HQ for EMT -Interface between eFPGAsim, SPS, PLECS and SPICE available for EMT
	CIM Common Interface Model See next slide	

CHALLENGES & SOLUTIONS FOR DISTRIBUTION SYSTEMS

Challenges:	**DATA MANAGEMENT & SYSTEM DIAGRAM** **Finding a common data based for all simulation tools (different types of simulation and different vendor tools**	
	Solution (Opal—RT Plan)	Status (as of Sept 30, 2012)
Interface between EMT tools and Phasor-type tools	CIM- Extension of CIM for EMT simulation (need mode data)	-Participation in IEEE committe -The work is very slow even if the 5 main off-line tool organisation sare participating (EMT-RV, PSCAD, SPS, eMEGAsim, HYPERSIM) -lack of expertise and financing -Participation of only one real-time simulator vendor (OPAL-RT only)
	CIM EMT Extension with partners commercial solution a with CIM compatible data based and schematic editor start to emerge	-OPAL-RT is looking for partners to accelerate the solution to this problem - the investment will not be negligible -The benefits may be more important for users than for real-time simulator and off-line tool vendors!

CHALLENGES & SOLUTIONS FOR DISTRIBUTION SYSTEMS

Challenges:	**LOAD AND POWER SYSTEM MODEL VALIDATION FOR DYNAMIC TRANSINTS**	
	Solution (Opal—RT - proposal	Status
Loads models and distributed generation systems for dynamic transients not validated (large faults and isanded modes)	-Collaboration with test laboratories - development of real-time model identification system for aboratory and field tests	
	- On-line stabilité monitoring and control?	

CHALLENGES & SOLUTIONS FOR DISTRIBUTION SYSTEMS

Challenges:	**MODEL VALIDATION – basic components and large models**	
	Solution (Opal—RT - proposal	Status
Model validation and limits not documented	Sharing models and analysis in the communoty	
	More education on test and validation Not only on design Design for test!	